

procedures and to develop operational concepts for McTMA. Ames researchers used the knowledge gained in the site surveys to adapt TMA to Philadelphia and the surrounding Centers. Ames then conducted a series of real-time simulations—utilizing air traffic controllers and traffic managers from all of the affected facilities—of the arrival traffic feeding through the en route Centers into the Philadelphia TRACON. The results of the simulations defined the requirements for the system software architecture and the arrival traffic scheduling algorithms. Additionally, it was confirmed that because of the narrow geometry of many of the sectors, as well as crossing traffic bound for other busy East Coast airports, delay absorption would need to be allocated sector-by-sector. It was also determined that some delay would have to be

absorbed by sectors much farther upstream from the airport than expected. This is caused by the limited delay capacity of much of the airspace.

Additional simulations are planned and will be conducted at Ames and at the FAA's Technical Center over the next year. These simulations will be followed by an operational field test, beginning in early 2002 and lasting through 2004. Following successful completion of the McTMA field trials, the system will be handed off to the FAA for further deployment to selected sites throughout the United States.

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Mitigating Runway Incursions with Cockpit Display Technology

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Between 1988 and 2000 the U.S. Runway Safety Program Office (ATP-20) reported 3,420 runway incursions; 48% of these incursions were caused by pilots deviating from taxi clearances issued to them by air traffic control (ATC). Research at Ames Research Center has been conducted to identify the factors that contribute to these incidents and to develop cockpit display technologies to mitigate these and other errors in order to increase runway safety while simultaneously increasing efficiency.

Two full-mission surface-operations simulation studies were conducted in the Advanced Concept Flight Simulator (ACFS) at Ames. The ACFS was equipped with the Taxiway Navigation and Situation Awareness (T-NASA) display suite, which is composed of an electronic moving map (EMM) and a head-up display (HUD) to be used during taxi (see

fig. 1). The EMM presented an over-the-shoulder perspective view of the airport surface, location of own-ship in real time, and the taxi route clearance, textually and

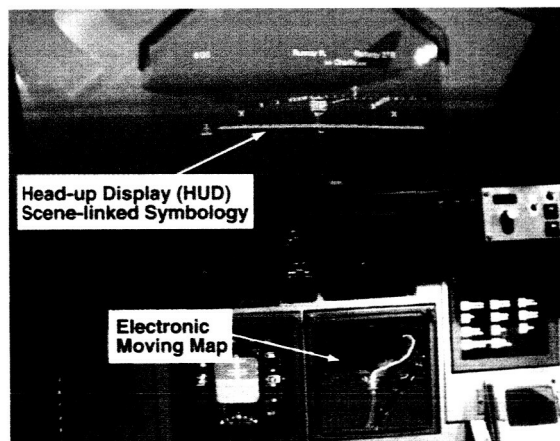


Fig. 1. The T-NASA System consists of an electronic moving map and a head-up display depicting the cleared taxi route transmitted via data-link ATC.

graphically. The HUD presented local guidance information via scene-linked symbols depicting the centerline and edges of the cleared taxiways. The ACFS was also equipped with advanced data-link technology that transmitted an electronic record of all ATC communications to the cockpit.

The simulations revealed that pilots committed navigation errors on 17% of land-and-taxi-to-gate trials in simulated low-visibility and night conditions. These navigation errors occurred as often during night conditions as during low-visibility conditions. An analysis of these navigation errors revealed three distinct classes of errors: (1) planning errors (formulating an erroneous understanding of the taxi route), (2) decision errors (making an incorrect turn choice at a taxiway intersection), and (3) execution errors (incorrectly maneuvering through an intersection).

Each class of errors had a unique set of contributing factors and mitigating solutions (see fig. 2). Planning errors occurred most often because of miscommunication between pilots and ATC. Technologies such as data-link and the T-NASA EMM that provide clear, unambiguous, and readily available representations

of the clearance were shown to mitigate these errors. Decision errors occurred because of high operational demands, as well as because of inadequate navigational awareness. The T-NASA HUD and EMM in combination reduced the number of these errors by providing pilots both global navigational awareness and local control guidance. Finally, execution errors were caused by inadequate or confusing environmental cues such as complex taxiway geometry, confusing signs and markings, and the "sea-of-blue lights" phenomenon (that is, the blue taxi lights form a confusing pattern when viewed off axis). The T-NASA HUD disambiguated the external environment cues and reduced the frequency of errors.

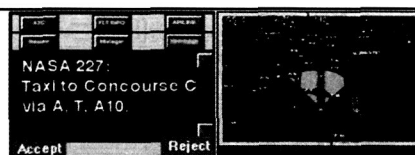
These studies revealed three classes of navigation errors: planning, decision, and execution. Further, it was shown that cockpit display technologies (such as T-NASA) that address these contributing factors can augment pilots' cognitive, decision making, and perceptual abilities, thereby resulting in fewer navigation errors and increased runway safety.

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PLANNING ERRORS

(Miscommunication / misunderstanding route)

Datalink (left) and T-NASA EMM (right) mitigate taxi route planning errors by enhancing Pilot-ATC communication & understanding of clearance.



DECISION ERRORS

(Making an incorrect turn decision)

Together the T-NASA EMM (left) and HUD (right) mitigate decision errors by enhancing navigational awareness, and lowering workload.



EXECUTION ERRORS

(Errors in maneuvering through an intersection)

The T-NASA HUD mitigates execution errors by disambiguating complex taxiway geometry and confusing airport signage and markings.



Fig. 2. The T-NASA cockpit displays mitigate navigation errors during surface operations, increasing taxi efficiency and safety.